Comparison of Observations and Theory for Ocean

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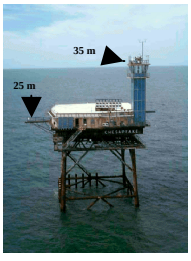
1. Introduction

COVE (CERES Ocean Validation Experiment) site (36.90N, 75.71W) is a rigid sea platform, which is 25km from Virginia Beach and is in water of 11m depth. It provides continuous long term radiation measurements. The altitude of the spectrophotometer SP1A at COVE is 23m.



COVE Site SP1A

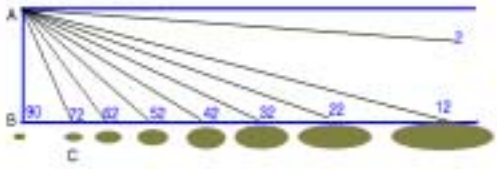
SP1A was also installed on the bow tower (16m above sea surface) on NOAA research vessel Ronald H Brown during the ACE-Asia cruise of March-April 2001 from Honolulu to Yokosuka, Japan (sponsored by Global Aerosol Climatology Project).

Ronald Brown SP1A

2. Instrument

SP1A has 18 channels with a fixed field of view of 1°. The SP1A is sufficiently stable over the huge dynamical range that is characteristic of sun glint. The SP1A is mounted on a seaworthy tracker and scans the ocean surface at 9 elevation angles (2, 12, 22, 32, 42, 52, 62, 72, and 90°); and for each elevation angle, it scans almost 180 degrees of azimuth. One set of measurements takes about 4.5 minutes. All results shown below are for 500 nm.

Measurement Scheme



AB equals height of SP1A

3. Simulation

Second Simulation of Satellite Signal in the Solar Spectrum (6S) model, which uses the *Cox-Munk* distribution of wave slopes to parameterize the effect of wind on reflection by the sea, is used to simulate the radiance (reflectance) observed by the SP1A. Input data needed for 6S are wind speed and direction, aerosol optical depth (AOD) at 550 nm and pigment concentration. Wind speed observed at different heights is scaled to the height of 10m.

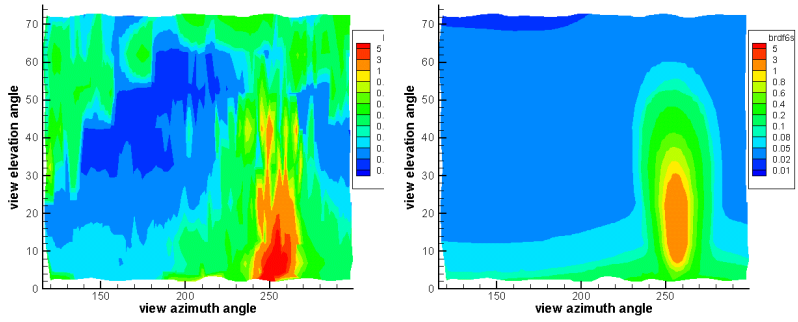
4. Results

Measurements are compared with the 6S simulations.

For the COVE site, measurements and simulations are averaged over six 5-minute intervals, using the same geometry and in situ wind speed and direction observations (5 minutes mean). AODs are obtained from AERONET measurements at the COVE site. Pigment concentration data are from SeaWiFS. AOD of Julian day 6, 2001 at COVE site is 0.056 at 550 nm.

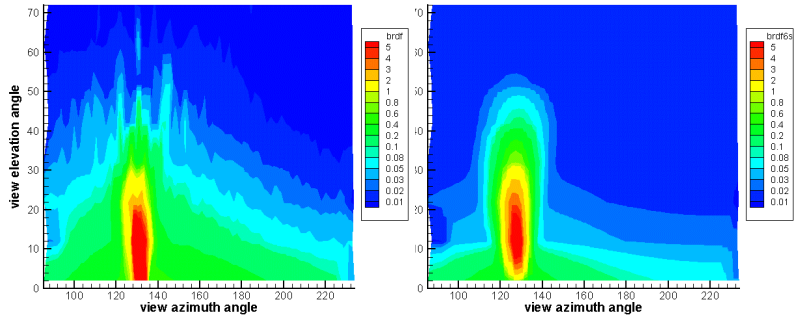
For the cruise data, pitch, roll, and heading corrections must be applied. Pitch and roll were measured by a clinometer with high viscosity damping fluid to filter out high frequency vibrations such as motor throb and propeller turning with a period of 200 ms. Heading data were provided by the ship's Scientific Computer System (SCS) with the period of 1 min. Since it is hard to have ship heading steady for 30 min, no averaging was applied to the ship data. The 5 min results are carefully chosen to have a heading change of less than 1 degree. AODs are from a handheld MicroTops sunphotometer. AOD of Julian day 88, 2001 on the ACE-Asia cruise is 0.1 at 550 nm.

Ron Brown: Measurement 6S Simulation



Comparison of observed and 6S simulated reflectance for 0615GMT of Julian day 088 on ACE-Asia cruise. Solar Zenith Angle is 63.9, Solar Azimuth Angle is 256.5. Wind speed is 7.6 m/s, and the wind direction is 144.3°.

COVE Site: Measurement 6S simulation



Comparison of observed and 6S simulated reflectance for 1300GMT of Julian day 006 at COVE site. Solar Zenith Angle is 83.1, Solar Azimuth Angle is 124.7. Wind speed is 5.8 m/s, and the wind direction is 251.4°.

Surface Reflectance for ACE-Asia and COVE Site

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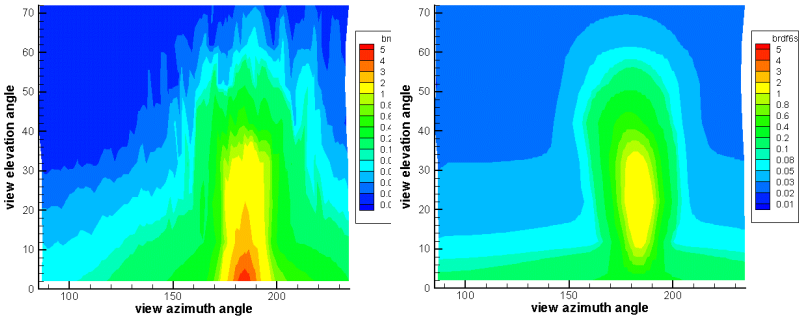
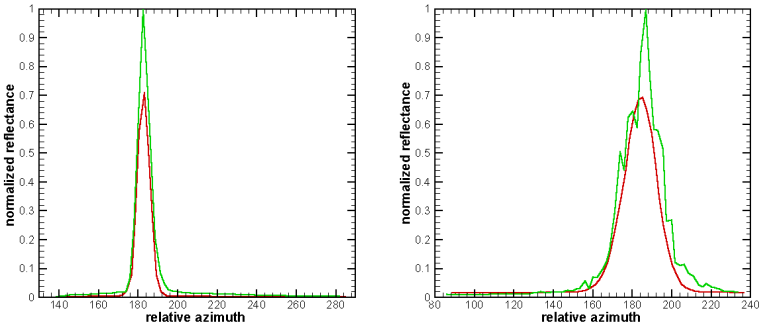
COVE Site: Measurement 6S simulation



Comparison of observed and 6S simulated reflectance for 1700GMT of Julian day 006 at COVE site. Solar Zenith Angle is 59.3, Solar Azimuth Angle is 178.0. Wind speed is 4.9 m/s, and the wind direction is 244.5º.

Simulations for different locations and times capture most of the glint characteristics measured by the SP1A. But the measured reflectance near the sun glint is greater than simulated; and the measured sun glint extends to a larger area.

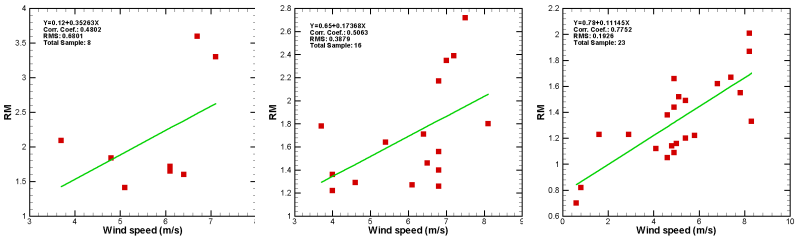
The reflectance can change by more than an order of magnitude in the sun glint area. Hence we normalize the observed and simulated reflectance by dividing them by the maximum reflectance. The normalized reflectance are plotted for specular viewing zenith angle. The sun glint area extends to a larger area at high sun than at low sun.



(a) (b)

Azimuthal distribution of observed (green) and simulated (red) normalized reflectance for (a) View Elevation Angle (VEA) of 12º for 13:30 GMT, Jan. 6, 2001 when Solar Zenith Angle (SZA) is 78.4º, and for (b) VEA of 32º for 17:00 GMT when SZA is 59.3º

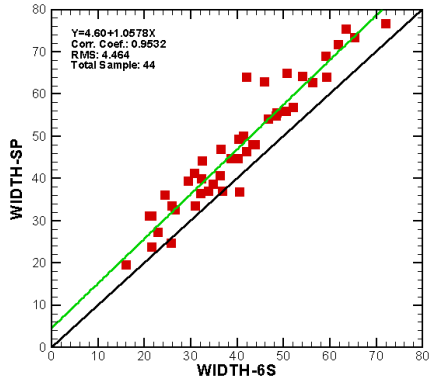
Define *RM* as the ratio of observed maximum reflectance to simulated maximum reflectance at the specular viewing zenith angle. The peak reflectance in the sun glint area is mainly determined by mean square slope(MSS), *RM* can be used as an indicator of the deviation of the real MSS to the one given by *Cox-Munk*. For each elevation angle, *RM* increases with wind speed, but *RM* decreases with increasing view elevation angles.



(a) (b) (c)

Regression relationships between RM, the ratio of maximum observed to maximum simulated reflectance, and wind speeds for elevation angles of (a) 12º, (b) 22º, and (c) 32º.

We investigate the width of sun glint by measuring the azimuth span where the normalized reflectance drops to 0.04 on each side of the specular point. It is clear that the observed sun glint covers a larger area than the simulated one.



Relationship between simulated and observed azimuth width of sun glint

5. Conclusions

- The measured sun glint shapes are in good agreement with the 6S simulations, but the measured reflectance is more intense and covers a larger area.
- *RM*, which is defined as the ratio of observed maximum reflectance to simulated maximum reflectance, can be used as an indicator of the deviation of the real mean square slope to the one given by *Cox-Munk*. *RM* increases with wind speed, but decreases with increasing view elevation angles.
- The width of the sun glint is defined as the azimuth span for normalized reflectance greater than 0.04 on each side of the specular point. The observed width is larger than the simulated.

Reference

Cox, C., and W. Munk, Measurement of the roughness of the sea surface from photographs of the sun's glitter, *J. Opt. Soc. Am.*, 44, 838-850, 1954.

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